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TWIN-ROTOR PATROL AIRSHIP FLYING MODEL DESIGN RATIONALE

John A. Eney
Aircraft and Crew Systems Technology Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

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To gain experimental data on the controllability of tilt-rotor airships operating near neutral buoyancy, a 32-foot long 1/10 scale flying model is being developed using two contrarotating tilt-rotor representing those on the NASA/Bell XV-15 research aircraft. It is planned to demonstrate controlled hover and transition in an engine - out condition with one rotor stopped to emphasize the natural attitude stability and damping of such vehicles.

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ABSTRACT

To gain experimental data on the controllability of tilt-rotor airships operating near neutral buoyancy, a 32-foot long 1/10 scale flying model is being developed using two contrarotating tilt-rotors representing those on the NASA/Bell XV-15 research aircraft. It is planned to demonstrate controlled hover and transition in an engine - out condition with one rotor stopped to emphasize the natural attitude stability and damping of such vehicles.

INTRODUCTION

As an outgrowth of recent studies assessing the utility and effectiveness of lighter-than-air vehicles in maritime patrol functions, an experimental model flight test program is being initiated at this Center. A 32-foot long 1/10 scale flying model is under construction which will be used to gain data on the controllability of tilt-rotor VTOL airships operating near neutral buoyancy. Initially, a twin rotor design will be tested, using rotors scaled to represent those on the NASA/Bell XV-15 research aircraft. Follow-on testing is planned for tri- and quadrotor configuration modifications using the same baseline hull and empennage.

BACKGROUND

Airships ceased operation in the Navy in 1962 for reasons that continue to arouse controversy at the present time. The recognition of an energy shortage in 1974 and the since escalating cost of petroleum has resulted in a series of paper studies hypothesizing second generation airships with "precision hover capability" performing missions which emphasize endurance over speed. When it is assumed that the inherent fuel economy of an airship is not defeated by the implementation of an as yet undefined hoverable propulsive lift system, such vehicles take on high stature as candidate patrol/surveillance platforms. Limited conceptual design studies have been conducted by industry under NASA and Navy contracts and have suggested, without a great deal of analytical substantiation, several propulsive lift systems on a conventional non-rigid airship hull.

PROPOSED CONCEPTUAL DESIGNS

In the patrol class of mission, long duration on station in a loiter mode drives the design toward a fully buoyant conventional airship, as opposed to a hybrid with aerodynamic lift from a shaped body supplementing the buoyant lift. Ordinarily, the installed power would solely be determined by drag at a transit or dash speed. By stipulating a true VTOL capability at takeoff, the propulsion may be sized by the degree of heaviness that exists at takeoff with full fuel, which in turn is a function of specific fuel consumption, range to station, time on station, and ground rules concerning mid-mission refueling and ballasting. Typically, the buoyancy ratio (β) at takeoff is about 0.85. A propulsive lift system must then provide thrust slightly greater than 15% of the takeoff gross weight, as a minimum.

The number and placement of propulsive lift devices is determined by the desire to provide controllability in hover. Several companies have espoused their own preferred configurations, as shown in the accompanying figures.

The quadrotor shown in Figure 1, originated by the Piasecki Aircraft Company, mounts four fixed helicopter rotors for lift, attitude control, and translational thrust. Forward thrust can be augmented by adding propellers which also augments yawing moment control in hover.

A mutation of the quadrotor (Figure 2) has been proposed by Bell Aerospace Textron, where two diagonally opposed rotors carry a steady DOWN load while the others produce an equal upward force. In this way, significant rotor lift forces are available for cyclic deflection to produce translational forces and yawing moments in a neutrally buoyant state ($\beta = 1.0$).

Figure 3 depicts the trirotor proposed by the Goodyear Aerospace Corporation. Two tilting propellers are mounted forward on the hull and a third is at the stern. Movable surfaces on an inverted "V" tail supporting the stern propeller, and on the wings supporting the main propellers, provide forces and moments in the horizontal plane during hover. Hover control diminishes as β approaches unity. A notable advantage in the trirotor concept is the low speed cruise efficiency of a stern propeller. To take full advantage of this aspect of the design, the main propellers could be stopped and folded against the nacelles to reduce drag.

TWIN ROTOR DESIGN PHILOSOPHY

The Navy model under construction (Figure 4) will initially be tested as a twin rotor configuration, using a proportionately scaled propulsion system representing that of the NASA/Bell XV-15 tilt rotor research aircraft. This arrangement has been selected for initial evaluation based on the following considerations:

- The total static thrust of the XV-15 rotor system is in close proximity to that required for the 0.8 - 1.1 million cubic foot airships which match currently proposed maritime patrol mission profiles. (Reference (1))

- The development of a new engine/rotor for full scale prototyping of an airship is unlikely (at present).

- The load distribution on the twin-rotor hull is similar to that of past conventional airships.

- Simplicity of the classic airship is least compromised. (fewest added moving parts)

- All engines and rotors sit relatively low and lend themselves to simple work stands and mobile hoists for maintenance.

MODEL FEATURES

The model being constructed is a 1/10 scale rendition of an 875,000 cubic foot maritime patrol airship. Detail design has been performed by Lancaster Analytics, Incorporated of North Canton, Ohio under NAVAIRDEVCEN Contract N62269-80-M-3333. Specifications for the model are listed in Table 1.

The tiltrotor propulsive lift system uses true 1/10 scale XV-15 nacelles and rotors, with the rotor spacing increased. The rotors are placed under the center of buoyancy to avoid exciting pitch oscillations with thrust changes in hover. Power is supplied by one single-cylinder 2-cycle reciprocating Webra engine mounted inside the car and driving both rotors through a common connecting shaft. A centrifugal clutch, shown in Figure 5, engages the engine to a belt reduction drive and thence to a transmission with output shafts to each rotor outrigger. A second clutch, servo controlled, is mounted on the starboard outrigger shaft to allow disengagement of that rotor for single rotor demonstrations. 90° gearboxes in each nacelle output short shafts turning at 1475 rpm to each of the three-bladed contra-rotating rotors. Servoes in each nacelle control cyclic and collective pitch through a conventional swashplate and pitch link system. Rotor system detail design and fabrication was performed by Faye Peoples, Incorporated of Warminster, Pennsylvania under NADC Contract No. N62269-80-M-5159.

The 32-foot long, 875 cubic foot hull is a non-rigid envelope made up in 12 gores from 3.8 oz. rip-stop nylon coated with a white urethane finish. To simplify knockdown and reerection of the model for transport, no internal suspension cables or ballonets are used. The car laces to the belly of the bag through the fabric fillet or car fairing. The welded aluminum tube truss frame of the car (Figure 6) extends up into a notch in the bag to form a rigid tunnel for the carry-through structure of the outriggers.

To compensate for changes in helium volume due to leakage and variations in ambient air pressure and temperature, an external bladder or nurse bag will be connected to the hull through a valve built integral with the mooring fitting on the bow. This system is designed to maintain nominally 2-1/2" of water pressure in the hull when moored.

MOORING SYSTEM

Again in the interest of providing a quick knockdown and reassembly capability, the normal stiffening battens on the bow of the model have been deleted in favor of a large welded truss cone permanently attached through a universal joint to the mobile mooring mast (Figure 7). The cone assembly is made from 6061 aluminum tubing and sheet stock. The tripod mast is steel tubing, mounted on casters for easy towing. Ballast and tie down fittings are provided. The mooring system is designed to restrain the model in a 90 KT wind.

FLIGHT CONTROL SYSTEM

Commercial Kraft radio control equipment is employed to operate the rotor system and the tail surfaces. Four receivers are used to provide signals to 14 command channels. Each of three fins houses a receiver and servo to move the control surface attached, one rudder and two ruddervators in the inverted "Y" tail arrangement. This avoids long wire runs and connectors on the envelope. Antennas are integral within each fin.

The rotor system is operated by the fourth receiver mounted inside the car which controls engine throttle setting, tilt of the nacelles, and rotor cylcic pitch (2 axes).

FABRICATION STATUS

Rotor System

The entire power train, including engine, clutches, belt drive reduction, torque tubes, drive shafts, nacelles and 3-bladed rotors is expected to enter runup testing at the contractor's facility in July 1981.

Hull (Bag)

The 875 cubic foot envelope is the subject of a competitive procurement with bids expected from the following three firms:

a. ILC Dover
   Frederica, Delaware
b. L'Garde, Inc.
   Newport Beach, California
c. Raven Industries, Inc.
   Sioux Falls, South Dakota

This procurement will also provide the car fairing and the nurse bag.

CAR, EMPENNAGE, MOORING MAST

These items are being fabricated by the model shop at the NASA Ames Research Center under MIPR No. N62269-81-MP-00036.

TEST PLAN

Initial flights will be inside the hangars at NAVAIRDEVCEN. A lightweight instrumentation package will be fitted to record roll, pitch, and yaw attitudes in response to control inputs in a turbulence free indoor environment. As confidence and skill develops, full transitions will be conducted inside one of the remaining airship hangars at the Naval Air Engineering Center. Lakehurst, New Jersey.

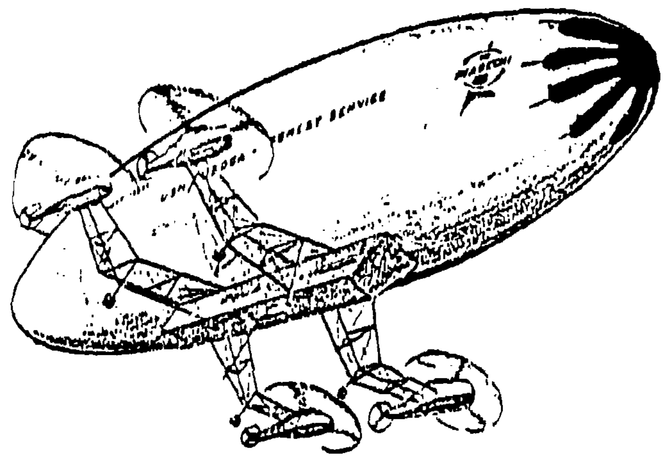

FIGURE 1. Piasecki "Helistat" Quadrotor Heavy-Lift Airship for U.S. Forest Service (Artist's Rendering).

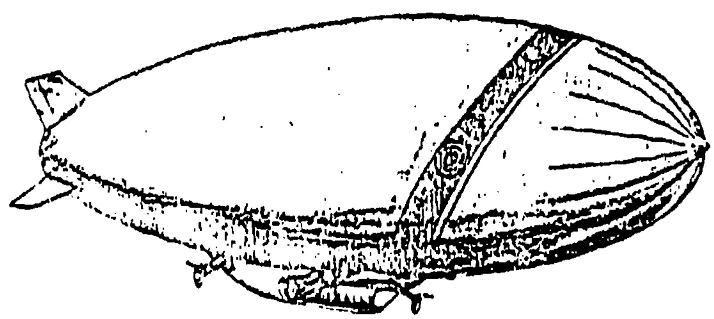

FIGURE 2. Bell Aerospace Textron Quadrotor Patrol Airship for U.S. Coast Guard (Artist's Rendering).

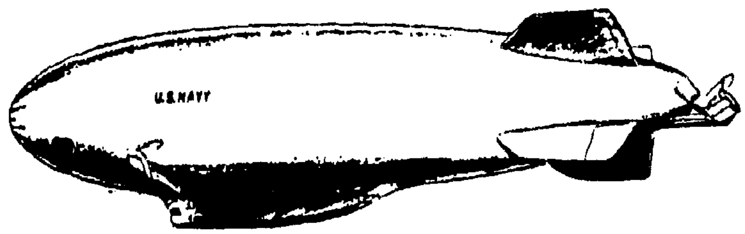

FIGURE 3. Goodyear Aerospace Trirotor Patrol Airship (Artist's Rendering).

Table 1: Model Specifications

Hull Volume	875 cu ft
Fineness Ratio	4.37
Length	32.1 ft
Maximum Diameter	7.47 ft
Gross Static Lift	57.5 lbs
Empty Weight	56.8 lbs
Static Rotor Thrust	15.6 lbs
Rotor Diameter	30 in
Maximum Speed	35 KT

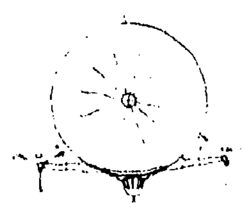

FIGURE 4. General Arrangement Drawing of 1/10 Scale Twin-Rotor Patrol Airship Flying Model.

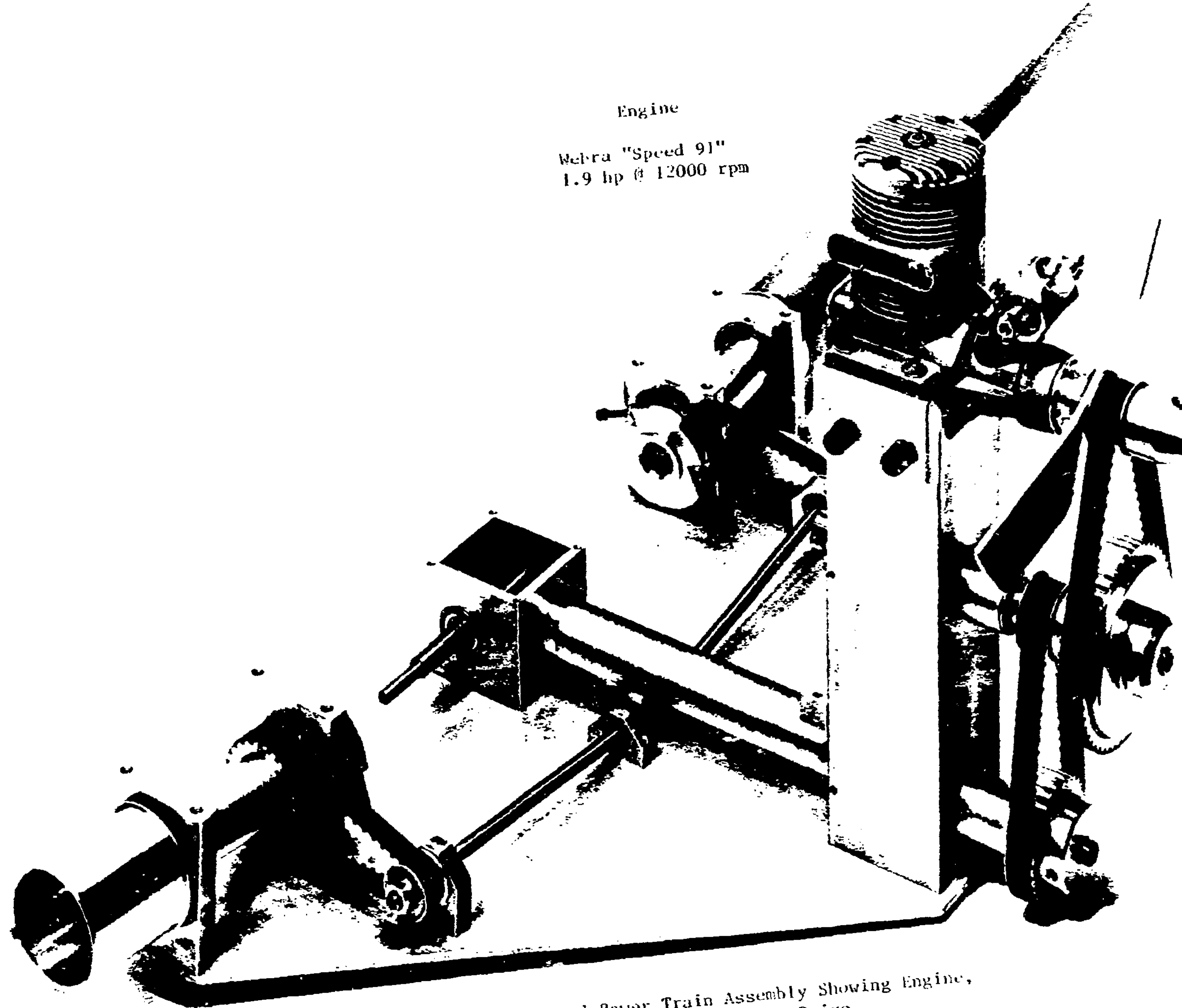

FIGURE 5. Partially Completed Power Train Assembly Showing Engine, Centrifugal Clutch, and Reduction Belt Drive.

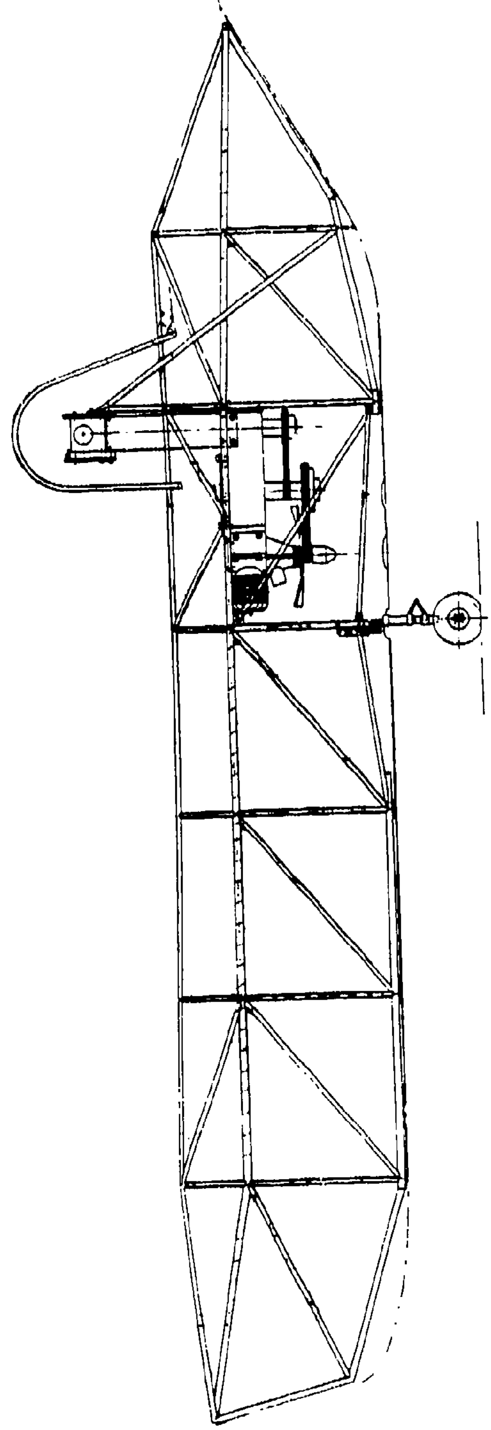

FIGURE 6. Car Frame Side View Showing Drive System Installation and Landing Gear.

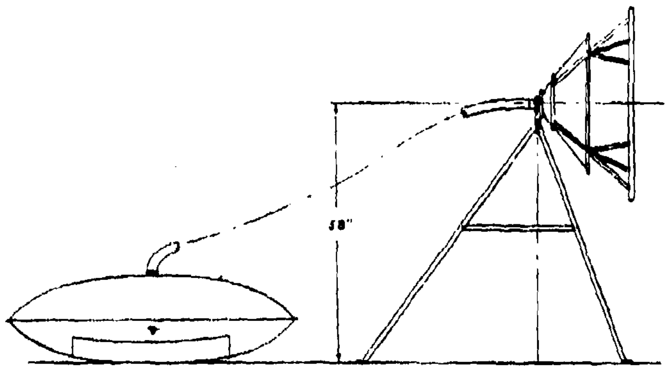

FIGURE 7. Mooring Mast and Cone Assembly With Nurse Bag.